

CLAIMS

We claim:

1. A method of generating kinetic power for propulsive force in a lower extremity prosthesis including a foot, an ankle and an elongated, upstanding shank above the ankle, the method comprising:

providing a monolithically formed resilient member which forms the ankle and the shank in the prosthesis with the resilient member at least in the area of the ankle being anterior facing convexly curved; and

assisting posterior movement of the upper end of the resilient member and controlling anterior movement of the upper end of the resilient member during use of the prosthesis.

2. The method according to claim 1, wherein said assisting posterior movement includes resiliently biasing the upper end of the resilient member for posterior movement using a device provided on the prosthesis.

3. The method according to claim 1, wherein said controlling anterior movement limits the range of anterior movement of the upper end of the resilient member using a device provided on the prosthesis.

4. The method according to claim 1, wherein said controlling the anterior movement includes resisting the anterior movement of the upper end of the resilient member using a device provided on the prosthesis.

5. The method according to claim 1, wherein said controlling the anterior movement includes resiliently biasing a device on the prosthesis during anterior movement of the upper end of the resilient member to store energy in the device with force loading of the prosthesis in gait, the device returning the stored energy during force unloading of the prosthesis adding to the propulsion of the person's body in gait.

6. The method according to claim 1, wherein said assisting and said controlling increase the ankle torque ratio of the prosthesis in gait, the ankle torque ratio being defined as the quotient of the peak dorsiflexion ankle torque that occurs in the prosthesis in the late terminal stance of gait divided by the plantar flexion ankle torque created in the prosthesis in the initial foot flat loading response after heel strike in gait.

7. The method according to claim 6, including increasing the ankle torque ratio to mimic the ankle torque ratio which occurs in a human foot in gait.

8. The method according to claim 6, including increasing the ankle torque ratio so that said peak dorsiflexion ankle torque is an order of magnitude greater than said plantar flexion ankle torque.

9. The method according to claim 6, including increasing the ankle torque ratio to a value of about 11 to 1.

10. The method according to claim 1, including providing the foot with a high low dynamic response capability.

11. The method according to claim 10, wherein said foot includes a foot keel and said providing the foot with high low dynamic response capability includes forming a midfoot portion of the foot keel with a longitudinal arch with a medial aspect larger in radius and with a relatively higher dynamic response capability than a lateral aspect of the arch.

12. A prosthetic foot comprising:

a longitudinally extending foot keel;

a resilient calf shank having a lower end connected to the foot keel, an anterior facing convexly curved lower portion extending upwardly from the lower end, and an upper end to connect with a lower extremity prosthetic socket on a person's leg stump, the upper end being

moveable longitudinally of the foot keel in response to force loading and unloading of the calf shank during use of the prosthetic foot; and

a device connected to an upper portion of the calf shank and a lower portion of the prosthetic foot to assist posterior movement of the upper end of the calf shank and to control anterior movement of the upper end of the calf shank.

13. The prosthetic foot according to claim 12, wherein the device includes at least one flexible strap allowing limited elastic extension.

14. The prosthetic foot according to claim 13, wherein the device includes means for adjustably tensioning the at least one strap.

15. The prosthetic foot according to claim 12, wherein the lower portion of the prosthetic foot to which the device is connected is one of a lower portion of the calf shank, the foot keel, and a coupling element connecting the calf shank and foot keel.

16. The prosthetic foot according to claim 12, wherein the device is located posterior of the calf shank.

17. The prosthetic foot according to claim 12, wherein the device includes at least one flexible strap connecting the upper portion of the calf shank and the lower portion of the prosthetic foot, and at least one spring which is resiliently biased by the at least one strap in response to anterior movement of the upper end of the calf shank for storing energy.

18. The prosthetic foot according to claim 17, including means for adjusting the length of the strap to permit preloading the at least one spring.

19. The prosthetic foot according to claim 17, wherein the at least one spring is adjacent to the at least one flexible strap to cause a change of direction in the strap.

20. The prosthetic foot according to claim 17, wherein the at least one flexible strap is connected to a resilient portion of the foot keel which serves as said at least one spring.

21. A prosthetic foot comprising:

a longitudinally extending foot keel;

a resilient calf shank having a lower end connected to the foot keel, an anterior facing convexly curved lower portion extending upwardly from the foot keel, and an upper end to connect with a lower extremity prosthetic socket on a person's leg stump, the upper end being moveable longitudinally of the foot keel in response to force loading and unloading of the calf shank during use of the prosthetic foot;

a resilient posterior calf device connected to an upper portion of the calf shank and a lower portion of the prosthetic foot, the device flexing to store energy during force loading of the prosthetic foot and return the stored energy during force unloading to increase the kinetic power generated for propulsive force by the prosthetic foot in gait;

wherein the calf shank and the posterior calf device are monolithically formed.

22. The prosthetic foot according to claim 21, wherein at least the posterior portion of the foot keel is also monolithically formed with the calf shank and posterior calf device.

23. The prosthetic foot according to claim 21, wherein a lower end of the posterior calf device is pivotably connected to a posterior portion of the foot keel.

24. The prosthetic foot according to claim 21, wherein the foot keel is also monolithically formed with the calf shank and posterior calf device.

25. A prosthetic foot comprising:

a longitudinally extending foot keel;

a resilient calf shank having a lower end connected to the foot keel, an anterior facing convexly curved lower portion extending upwardly from the foot keel, and an upper end to connect with a lower extremity prosthetic socket on a person's leg stump, the upper end being moveable longitudinally of the foot keel in response to force loading and unloading of the calf shank during use of the prosthetic foot;

a resilient posterior calf device connected to an upper portion of the calf shank and a lower portion of the prosthetic foot, the device flexing to store energy during force loading of the prosthetic foot and return the stored energy during force unloading to increase the kinetic power generated for propulsive force by the prosthetic foot in gait;

wherein the prosthetic foot includes a plurality of longitudinal sections each including respective foot keel, calf shank and posterior calf device sections, the longitudinal sections at their distal ends being moveable independent of one another and at their proximal ends being

integral with one another.

26. The prosthetic foot according to claim 25, wherein the longitudinal sections includes sections of different widths.

27. The prosthetic foot according to claim 25, wherein the longitudinal sections include sections with foot keel distal surfaces at different heights.

28. The prosthetic foot according to claim 25, wherein there are three longitudinal sections arranged side by side with the central section having a foot keel distal surface at a height above the distal surface of the adjacent sections.

29. The prosthetic foot according to claim 25, wherein the longitudinal sections are each monolithically formed and are monolithically formed with one another at the proximal ends of their calf shank sections.

30. A prosthetic foot comprising:
a longitudinally extending foot keel;
a resilient calf shank having a lower end connected to the foot keel, an anterior facing convexly curved lower portion extending upwardly from the foot keel, and an upper end to connect with a lower extremity prosthetic socket on a person's leg stump, the upper end being moveable longitudinally of the foot keel in response to force loading and unloading of the calf shank during use of the prosthetic foot;

a device connected to an upper portion of the calf shank and a lower portion of the prosthetic foot to change the sagittal plane flexural characteristic for moving the upper end of the calf shank longitudinally with respect to the foot keel during use of the prosthetic foot; and

wherein the lower portion of the prosthetic foot to which the device is connected is one of a lower portion of the calf shank, the foot keel, and a coupling element connecting the calf shank and the foot keel.

31. A method of generating kinetic power for propulsive force in a prosthetic foot comprising:

providing a prosthetic foot having a longitudinally extending foot keel attached to a resilient calf shank which forms an ankle and a lower prosthetic part of a leg for connection with a lower extremity prosthetic socket on a person's leg stump, the calf shank including an anterior facing convexly curved portion extending upwardly from the foot keel and an upper end which during use of the prosthetic foot is moved longitudinally with respect to the foot keel in force loading and unloading of the prosthetic foot;

using a posterior calf device on the prosthetic foot to store energy during force loading of the prosthetic foot and return the stored energy during force unloading to increase the kinetic power generated for propulsive force by the prosthetic foot in gait;

wherein the storing of energy by the posterior calf device includes resiliently biasing at least one spring of the posterior calf device during anterior movement of the upper end of the calf shank.

32. The method according to claim 31, including initially loading the at least one

spring of the posterior calf shank to resiliently bias the upper end of the calf shank for posterior movement in gait.

33. The method according to claim 31, including adjusting the magnitude of the initial loading of the at least one spring for changing the relative flexure characteristic of the calf shank for posterior movement and anterior movement with force loading and unloading in gait.

34. The method according to claim 33, wherein said adjusting is performed such that the ankle torque ratio of the prosthetic foot in gait approaches that of a human foot, the ankle torque ratio being defined as the quotient of the peak dorsiflexion ankle torque that occurs in the prosthetic foot in the late terminal stance phase of gait divided by the plantar flexion ankle torque created in the prosthetic foot in the initial foot flat loading response after heel strike in gait.

35. The method according to claim 34, wherein said adjusting is performed to increase the peak dorsiflexion ankle torque that occurs in the late terminal stance of gait in the prosthetic foot and to decrease the plantar flexion torque created in the initial foot flat loading response after heel strike in gait so that the former is an order of magnitude greater than the latter.

36. The method according to claim 34, wherein the ankle torque ratio is increased to a value of about 11 to 1.

37. The method according to claim 31, wherein said foot keel includes a concavity

formed by a longitudinal arch in a midfoot of said foot, and wherein the concavity is expanded during said force loading to store energy and releases the stored energy in said later stages of stance-phase of gait to add to the propulsion force of the person's body.

38. The method according to claim 37, including forming the longitudinal arch with a medial aspect relatively higher in dynamic response capability than a lateral aspect of the longitudinal arch.

39. The method according to claim 37, including forming the longitudinal arch concavity with a medial aspect larger in radius than a lateral aspect.

40. A method of generating power for propulsive force in a prosthetic foot comprising:

providing a prosthetic foot having a longitudinally extending foot keel and a resilient calf shank forming an ankle and an elongated, upstanding shank above the ankle for connection with a lower extremity prosthetic socket on a person's leg stump, the calf shank including an anterior facing convexly curved lower portion extending upwardly from the foot keel and an upper end which during use of the prosthetic foot is moved longitudinally with respect to the foot keel during force loading and unloading of the prosthetic foot; and

changing the ankle torque ratio of the prosthetic foot in gait by using a posterior calf device on the prosthetic foot to affect a change in the sagittal plane flexure characteristic for longitudinal movement of the upper end of the calf shank in response to force loading and unloading during a person's use of the prosthetic foot, the ankle torque ratio being defined as the

quotient of the peak dorsiflexion ankle torque in the late terminal stance phase of gait divided by the plantar flexion ankle torque created in the prosthetic foot in the initial foot flat loading response after heel strike in gait.

41. The method according to claim 40, wherein the ankle torque ratio is changed to mimic that of a human foot.

42. A method according to claim 40, wherein the ankle torque ratio is changed so that the peak dorsiflexion ankle torque that occurs in the late terminal stance of gait is at least an order of magnitude greater than the plantar flexion ankle torque created in the initial foot flat loading response after heel strike in gait.

43. The method according to claim 40, wherein the ankle torque ratio is changed to about 11 to 1.

44. The method according to claim 40, wherein the ankle torque ratio is changed by using the posterior calf device to at least one of assist the posterior movement of the upper end of the calf shank and limit the anterior movement of the upper end of the calf shank.

45. The method according to claim 44, wherein the posterior calf device assists the posterior movement of the upper end of the calf shank by resiliently biasing the upper end for posterior movement.

46. The method according to claim 44, wherein the posterior calf device limits the anterior movement of the upper end of the calf shank by resiliently biasing at least one member of the posterior calf device during anterior movement of the upper end of the calf shank with force loading of the prosthetic foot to store energy for return during force unloading of the prosthetic foot.

47. The method according to claim 40, including monolithically forming the foot keel, calf shank and posterior calf device.

48. The method according to claim 40, including providing the foot keel with a resilient longitudinal arch which can be expanded in gait during force loading of the prosthetic foot for storing energy that is returned during force unloading.

49. The method according to claim 48, including forming the medial aspect of the longitudinal arch with a larger radius than the lateral aspect.